

LIDAR Intensity Images Balancing and Potentials

Riad Munjy, PE, Ph.D.

California State University, Fresno

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Introduction

- Despite the remarkable achievements in LIDAR technology and data processing, LIDAR intensity does not match the images produced by digital cameras.
- Recent new research effort by the author shows very promising results in improving the LIDAR intensity images that can be used in various mapping applications as an ortho-rectified imagery.
- The new approach has been applied on different commercial LIDAR systems with excellent success including RGB LIDAR imagery

Factors Affect Lidar Intensity

- Intensity is actually known to be a function of many variables
- The path length
- The local incidence angle that the laser beam makes with the footprint surface,
- Atmospheric attenuation,
- Transmit pulse energy of the laser
- The aggregate laser optics and receiver characteristics.

LIDAR Intensity

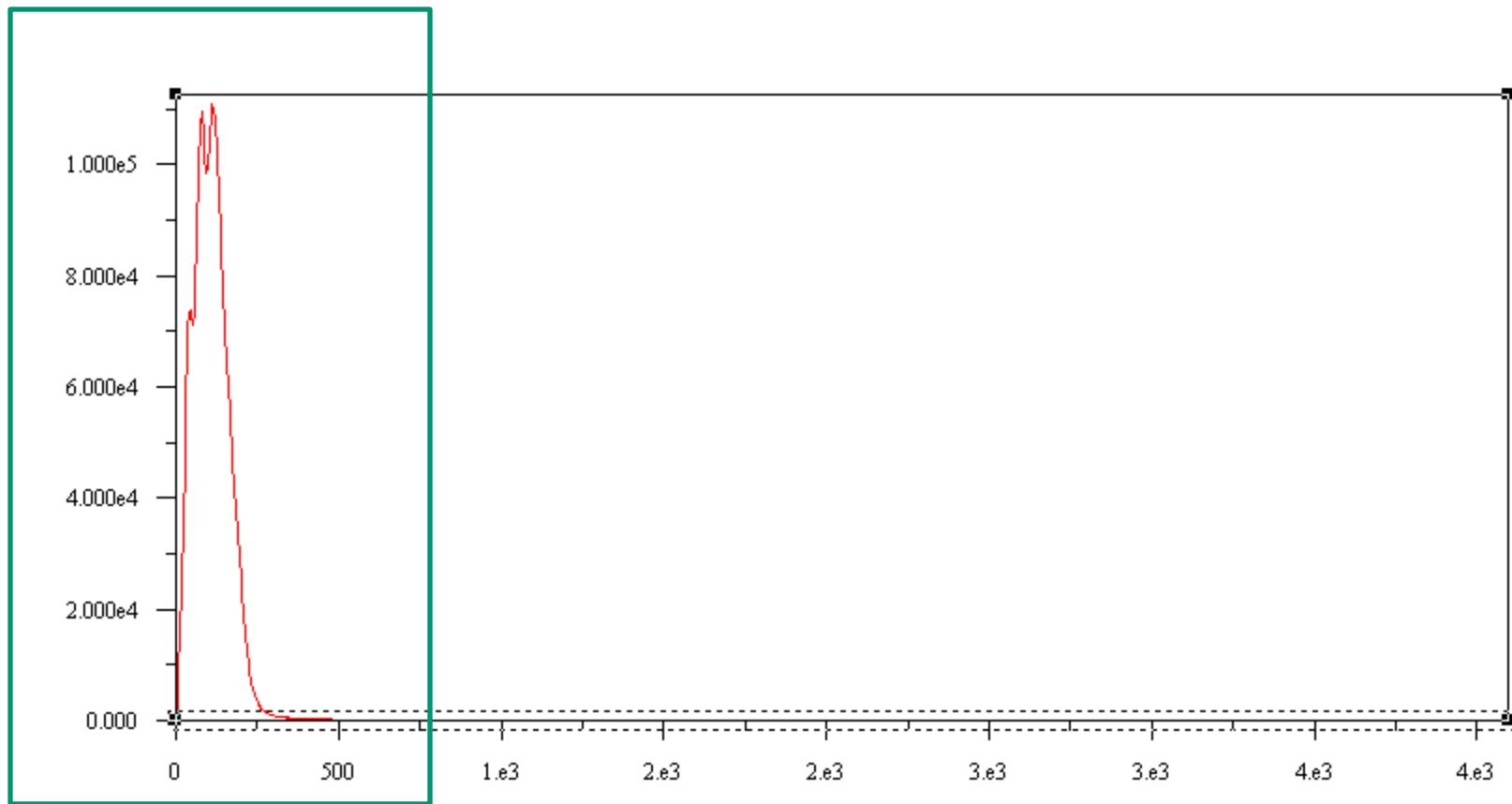
- Wavelength:
 - 1.045 - 1.065 µm (near infrared)
 - Color RGB
- Depth
 - 8,12 and 16 bits
 - Histogram Balance
- Random to Grid
 - TIN Model
 - Plane
 - Surface
 - Bilinear
 - Cubic convolution
 - Grid spacing?
 - Aliasing

Intensity Applications

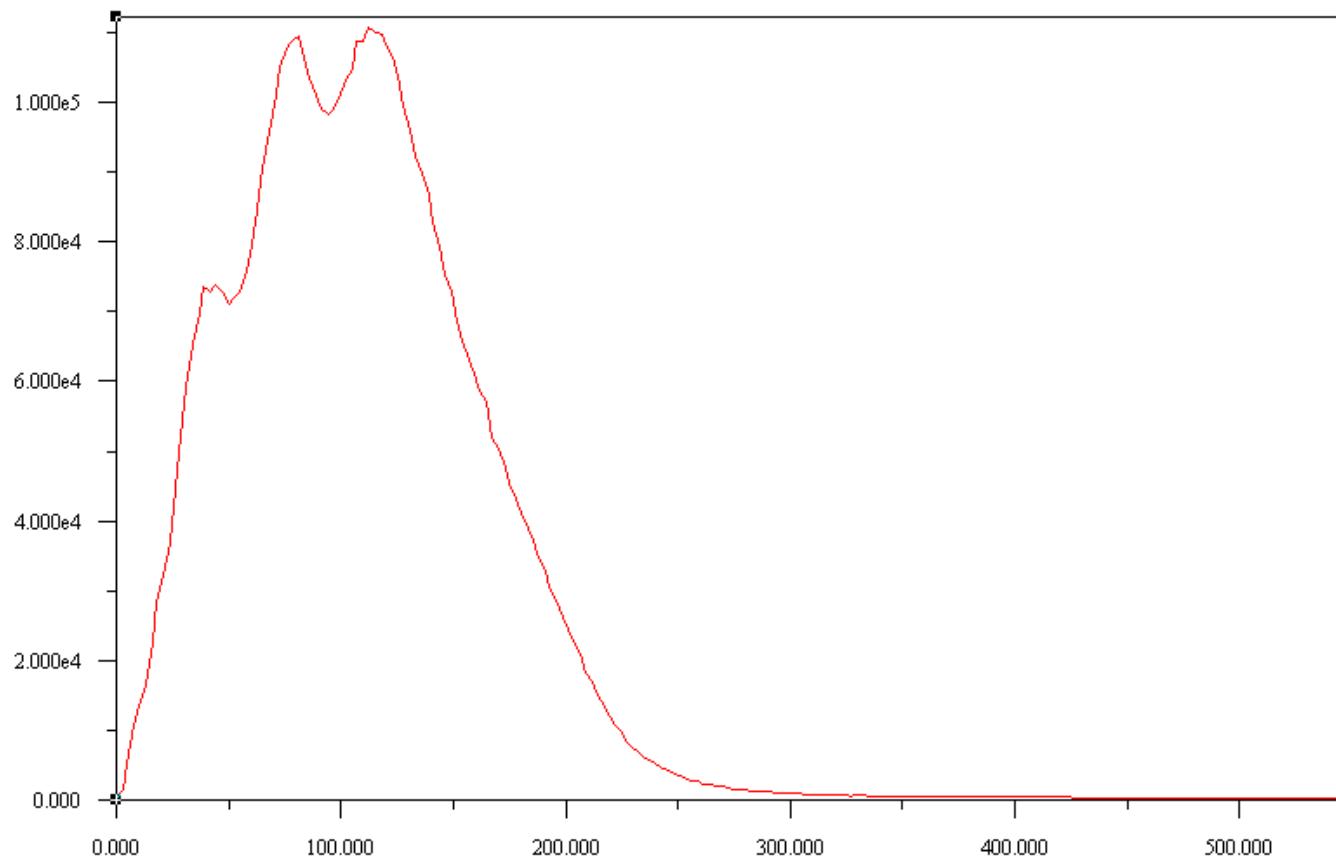
- Lidar strip adjustment
 - Lidar Block adjustment
- Estimating edge locations
 - Breaklines
- Classifications
- Stereo Lidar
- Ortho Image
 - Day and Night

Raw Data Histograms

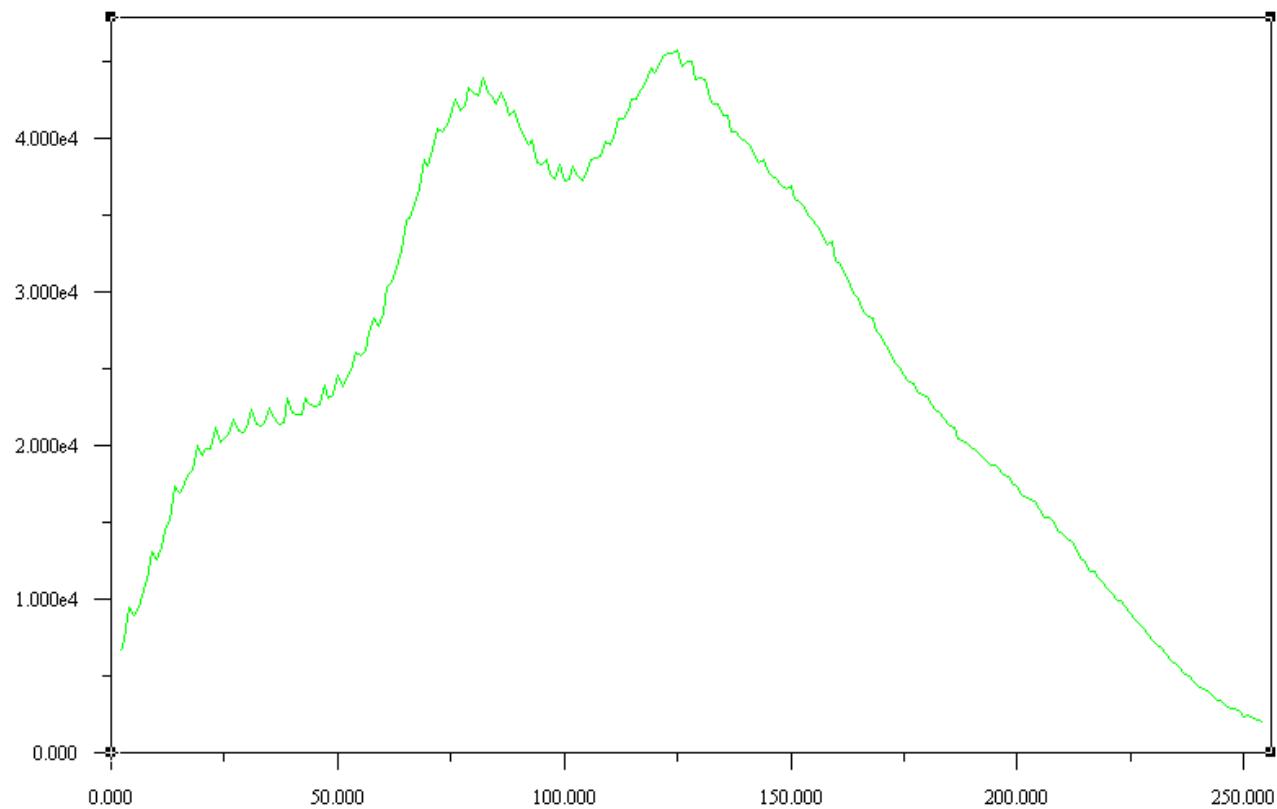
12 bit



Raw Data Histograms



New Histogram



Cubic convolution

- Cubic convolution can be computed row-by-row and then column-by-column.
- Assuming intensities at $u-1, u, u+1, u+2$ are $I(u-1), I(u), I(u+1), I(u+2)$, intensity at $0 < X < 1$ is estimated from $f(X) = I(u-1)f_{-1} + I(u)f_0 + I(u+1)f_1 + I(u+2)f_2$

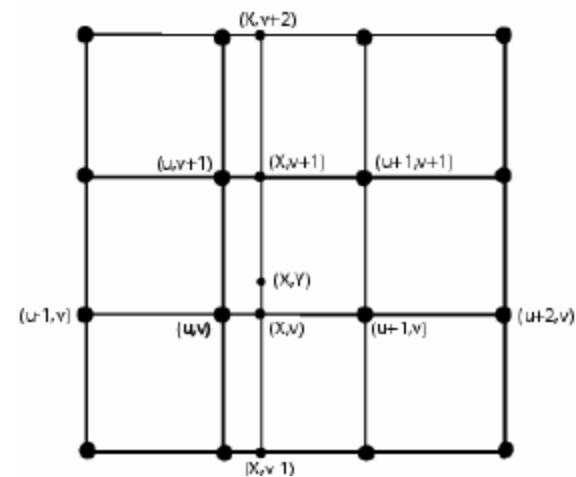
where

$$f_{-1} = -\frac{1}{2}t^3 + t^2 - \frac{1}{2}t,$$

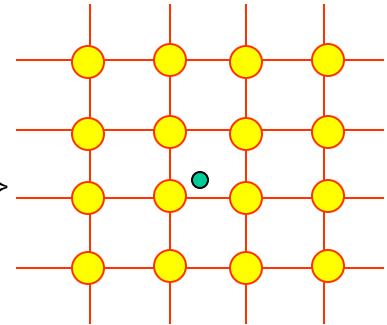
$$f_0 = \frac{3}{2}t^3 - \frac{5}{2}t^2 + 1,$$

$$f_1 = -\frac{3}{2}t^3 + 2t^2 + \frac{1}{2}t,$$

$$f_2 = \frac{1}{2}t^3 - \frac{1}{2}t^2,$$



Modified Cubic Convolution

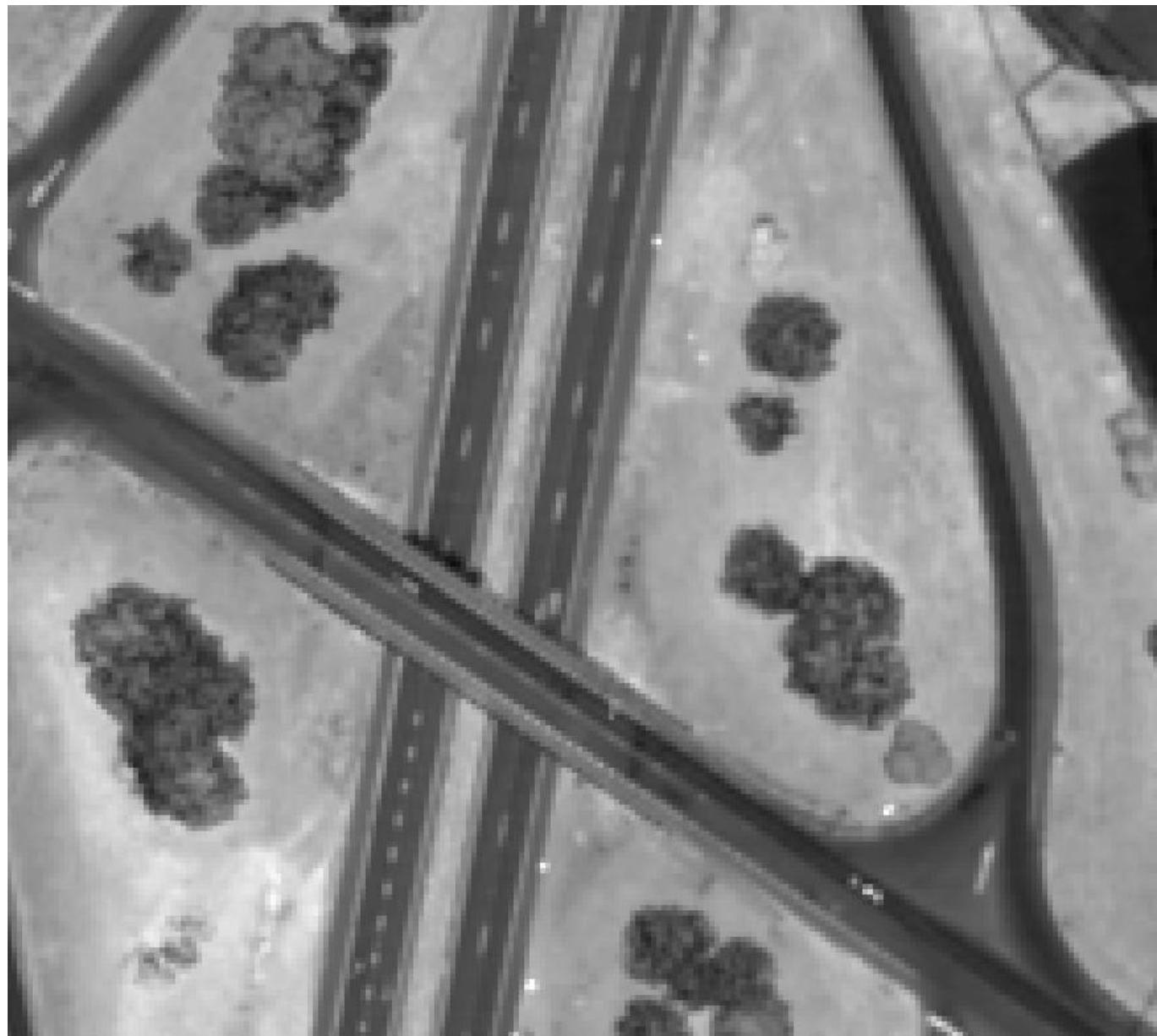
$$V_r = \sum_{n=1}^4 \left\{ \begin{array}{l} V(i-1, j+n-2) f(d(i-1, j+n-2)+1) + \\ V(i , j+n-2) f(d(i , j+n-2)) + \\ V(i+1, j+n-2) f(d(i+1, j+n-2)-1) + \\ V(i+2, j+n-2) f(d(i+2, j+n-2)-2) \end{array} \right\}$$


$$f(d) = \begin{cases} 1.5d^3 - 2.5d^2 + 1 & d < 1 \\ -0.5d^3 + 2.5d^2 - 4d + 2 & 1 < d < 2 \\ 0 & otherwise \end{cases}$$

LIDAR
Intensity
Mosaic
(5 Strips)
0.4 GSD
12 bits



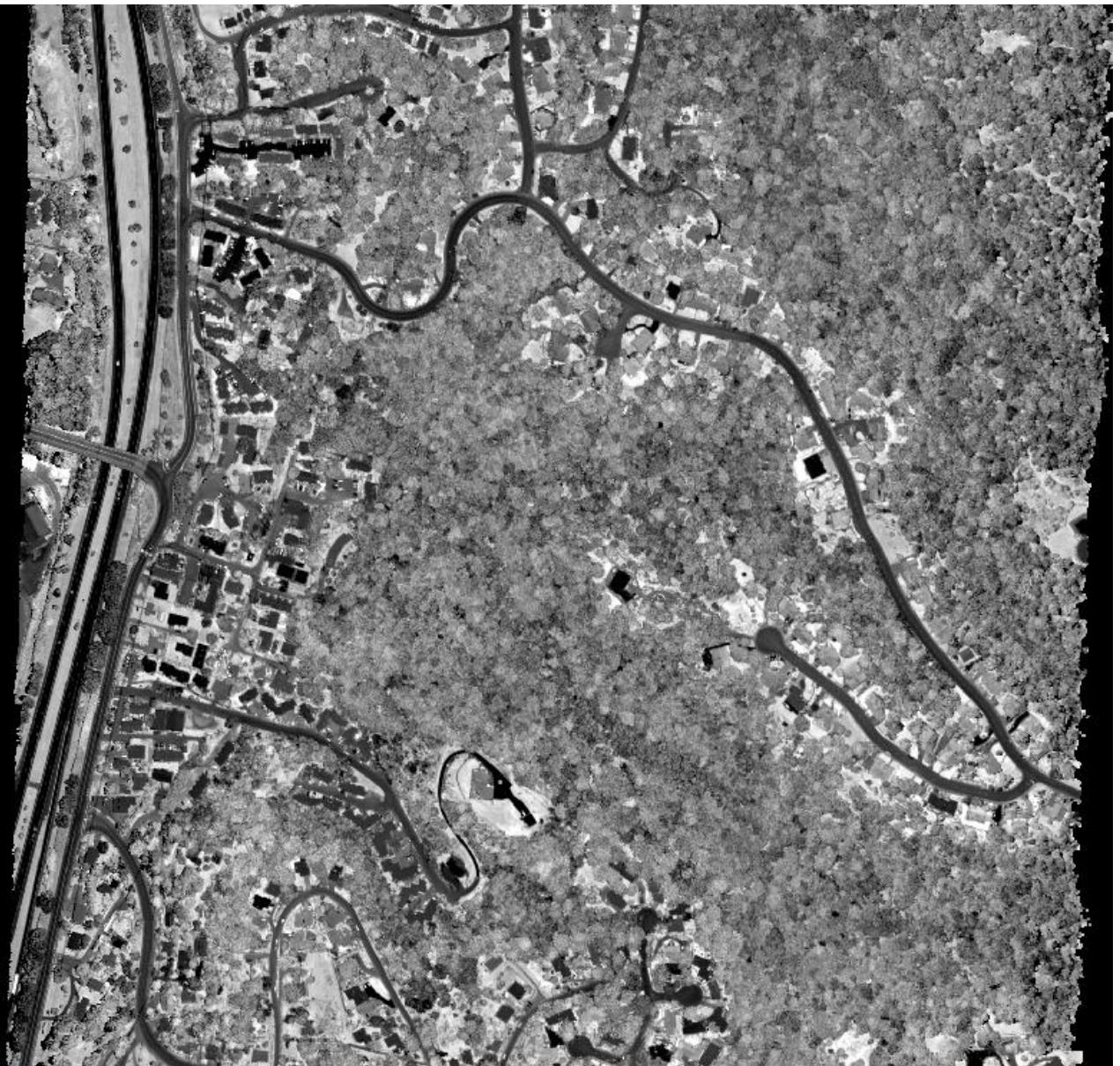
- 400% zoom



LIDAR
Intensity
Mosaic
(5 Strips)
0.4 GSD
12 bits



LIDAR
Intensity
Mosaic
(5 Strips)
0.4 GSD
12 bits



LIDAR
Intensity
Mosaic
(5 Strips)
0.4 GSD
12 bits



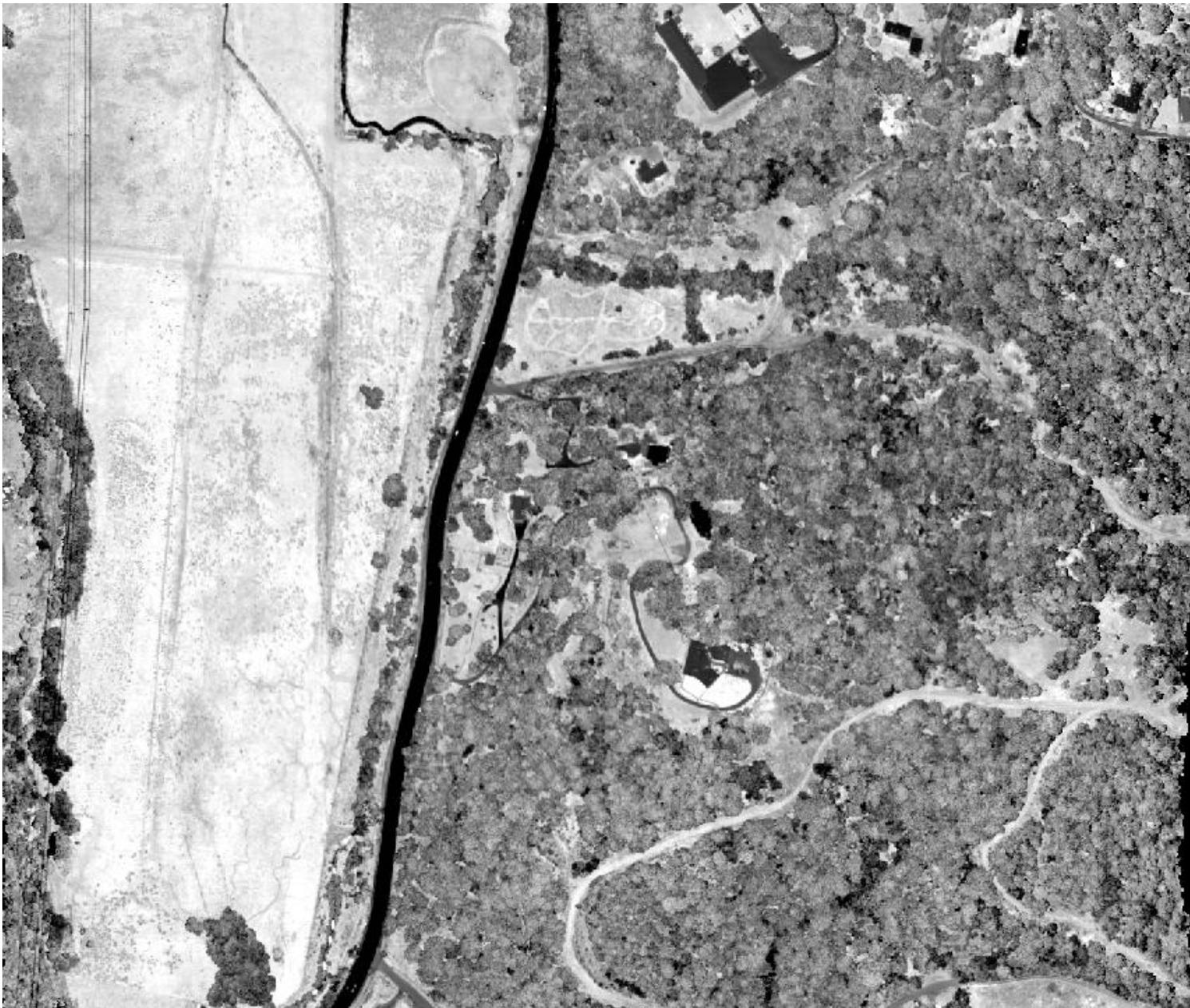
LIDAR
Intensity
Mosaic
(5 Strips)
0.4 GSD
12 bits



LIDAR
Intensity
Mosaic
(5 Strips)
0.4 GSD
12 bits



LIDAR
Intensity
Mosaic
(5 Strips)
0.4 GSD
12 bits



LIDAR
Intensity
Mosaic
(3 Strips)
0.5 GSD
12 bits

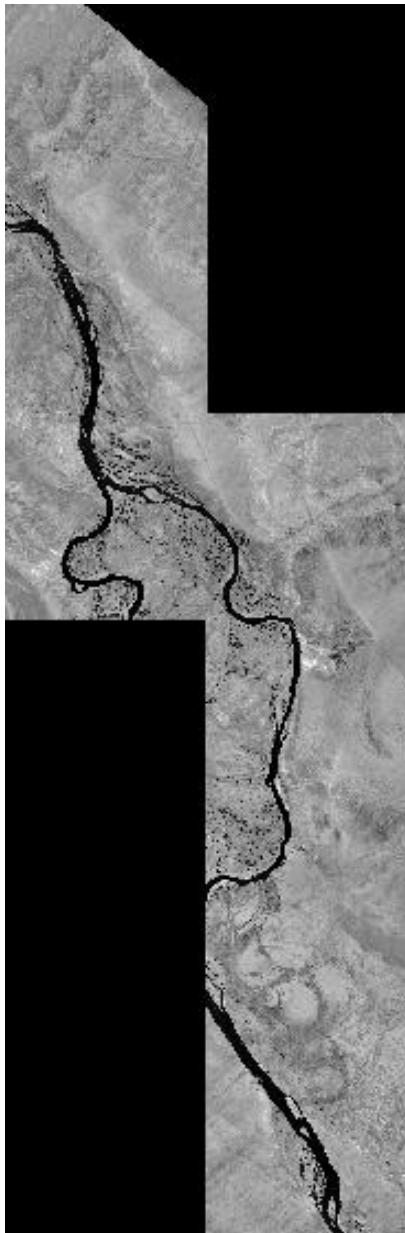




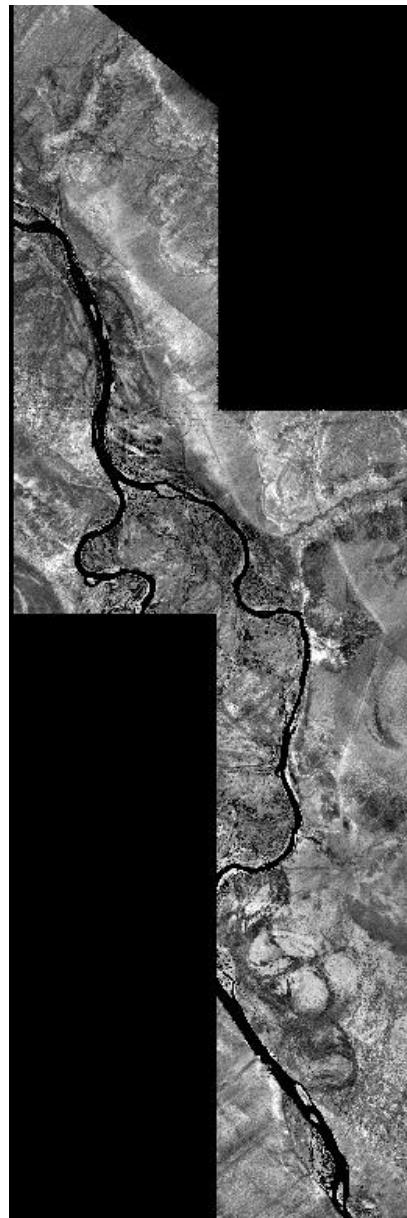
Google Imagery

LIDAR
Intensity
0.5 GSD
12 bits

Before



After



LIDAR
Intensity
Mosaic
(7 tiles)
1.0 GSD
8 bits

Google Imagery



Google Imagery (B/W)



LIDAR
Intensity
1.2 GSD
8 bits



B/W Google Imagery



LIDAR Intensity
1.2 GSD
8 bits

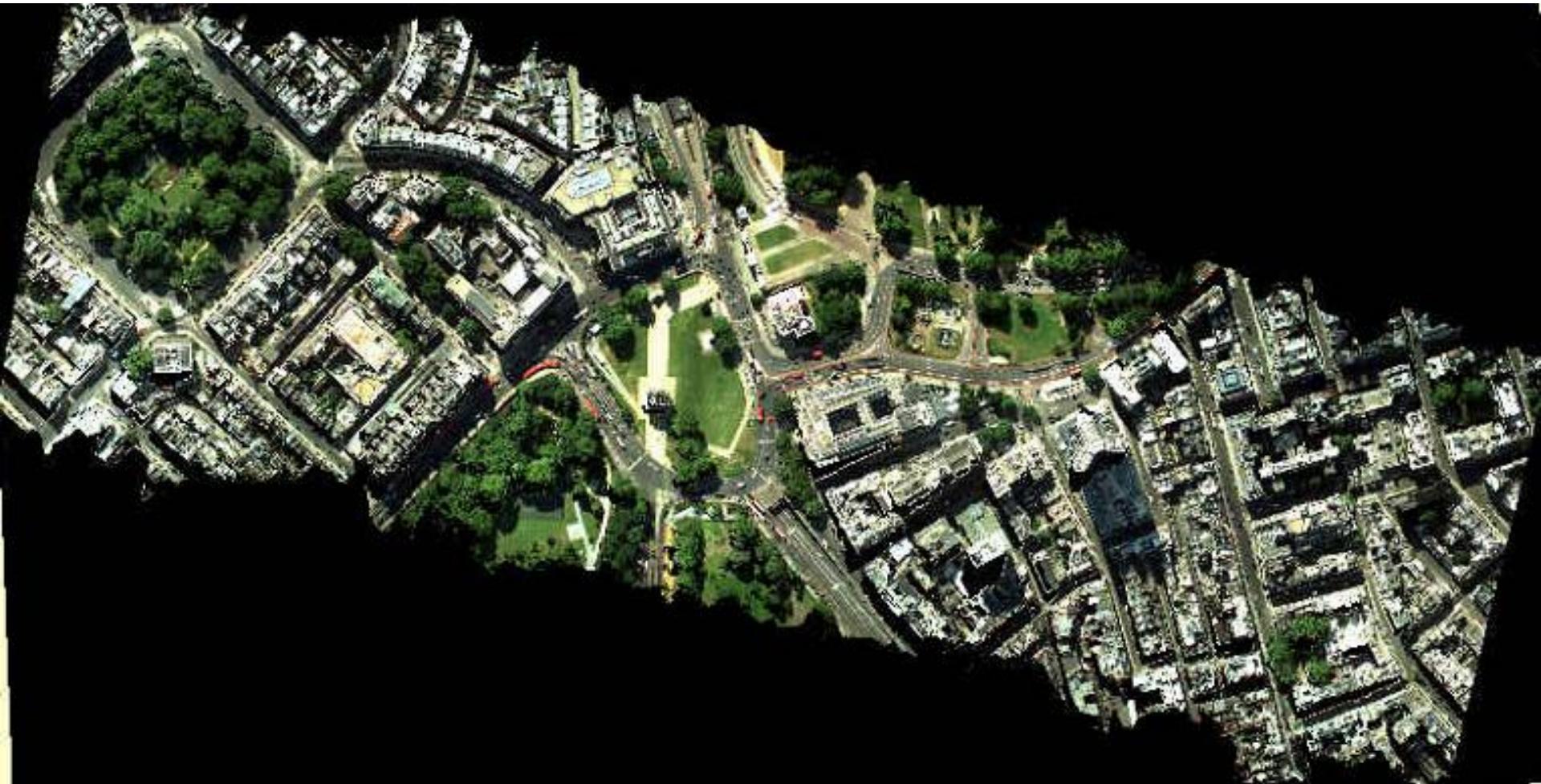


LIDAR
Intensity
Tile
0.3 GSD
8 bits



LIDAR Intensity Edges





RGB Lidar Point Cloud
20 cm



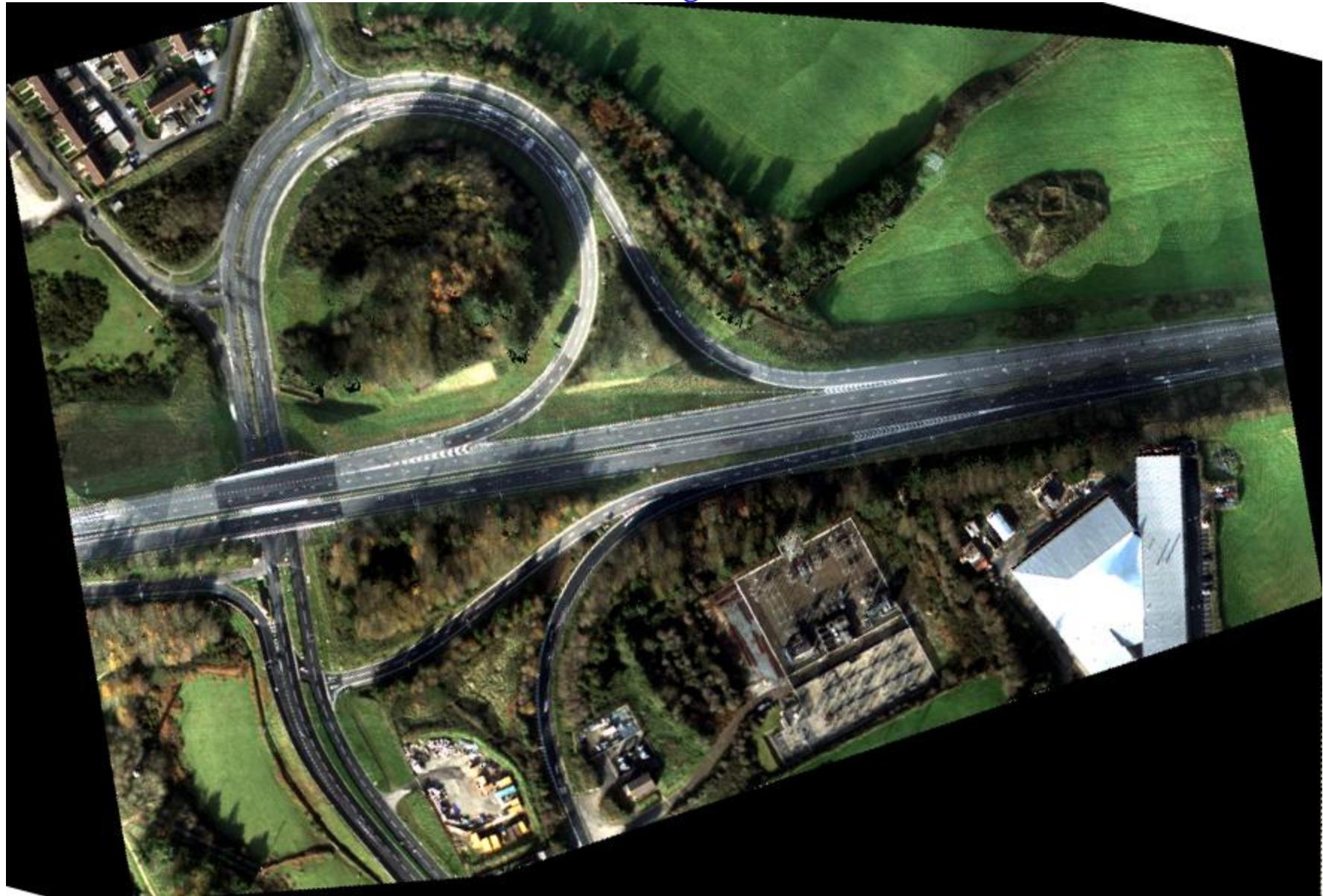
RGB Lidar Raster



Lidar Intensity Raster



Lidar RGB Raster
15 cm, 9 flight lines



Thank you
Questions

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